termined by the intersection of the line joining the slit and the grating, with a line drawn through the focus at a tangent to the circle having its centre in the middle of the line joining the grating with the focus. It is further suggested that the special qualities of a Rowland grating which are due to its astigmatism may be imparted to a "dioptric" spectroscope by giving a slight convex spherical curvature to one of the prisms, so that the instrument becomes slightly astigmatic.

THE INSTITUTION OF NAVAL ARCHITECTS.

LAST week the Institution of Naval Architects held their annual spring meeting, under the chairmanship of Admiral Sir John Dalrymple Hay, one of the Vice-Presidents of the institution, the President, Lord Brassey, being absent abroad. There was an unusually strong list of papers; perhaps almost too strong, for it was impossible to do justice to the sixteen contributions, to say nothing of the formal proceedings and the chairman's address, within the limited space of a three days meeting. Some of the papers might have been referred back to the authors with advantage, notably the two long contributions, one on the detachable ram, and the other on the comparative merits of the cylindrical and water-tube boilers.

The following is a list of the papers on the agenda:—(1) "The qualities and performances of recent first-class battle-ships," by W. H. White, C.B., Assistant-Controller of the Navy, and Director of Naval Construction; (2) "The amplitude of rolling on non-synchronous waves," by Emile Bertin, Directeur de l'Ecole d'Application Maritime, Paris; (3) "The stresses on a ship due to rolling," by Prof. A. G. Greenhill, Royal Artillery College, Woolwich; (4) "On Leclert's theorem," by Prof. A. G. Greenhill; (5) "Recent experiments in armour," by Charles E. Ellis, Managing Director of John Brown and Co., Limited, Sheffield; (6) "The detachable ram, or the submarine gun as a substitute for the ram," by Captain W. H. Jaques, late U.S. Navy; (7) "Leaves from a laboratory note-book: (*a*) some points affecting the combustion of fuel in marine boilers: (*b*) the spontaneous heating of coal," by Prof. V. B. Lewes, Royal Naval College, Greenwich; (8) "The circulation of water in Thornycroft water-tube boilers," by J. I. Thornycroft; (9) "On water-tube boilers," by J. T. Milton, Chief Engineer Surveyor Lloyd's Registry of Shipping; (10) "On the comparative merits of the cylindrical and water-tube boilers for ocean steamships," by James Howden; (11) "Further investigations on the vibration of steamers," by Otto Schlick; (12) "On the relation between stress and strain in the structure of vessels," by T. C. Read and G. Stanbury, assistants to the Chief Surveyor Lloyd's Registry of Shipping; (13) "Steam pressure losses in marine engines," by C. E. Stromeyer, Engineer Surveyor Lloyd's Registry of Shipping; (15) "Experience with triple expansion engines at reduced pressures," by D. Croll; (16) "Fluid pressure reversing gear," by David Joy.

M. Bertin's paper and Prof. Greenhill's second paper were taken as read.

Mr. White's contribution had been looked forward to with some interest, as it was anticipated that a somewhat lively discussion would ensue between the constructors of the Admiralty and naval officers on the question of the rolling of the *Resolution*, a subject dealt with by the author. Although the admirals mustered in some force, the discussion was of a very quiet nature, and the general opinion was that the *Resolution* and her sister-ships are perfectly safe vessels, and quite as well designed in regard to rolling capabilities as the tried battle-ships which have preceded them. That this fact could be shown by scientific reasoning was known beforehand to those acquainted with the elements of design of the ships, and having sufficient technical knowledge to draw conclusions from the premises. Nevertheless the doubts raised by the fact that the *Resolution* had put back to port after encountering a heavy storm in the Bay of Biscay, and the certainly extravagant newspaper reports of the occurrence were an unpleasant feature, especially as they appeared to be shared by a certain number of naval officers. It is well, therefore, that the discussion took place, and the matter has been set at rest. Mr. White's was a very long contribution, far too long for us to attempt even to abstract it here; but it was none too long for the patience of the meeting, as it was full of suggestive matter from beginning to end. The author dealt in a masterly way with the questions, in relation to battle-ships, of draught and trim, stability, metacentric height, curves of statical stability, period of oscillation, bilge keels, behaviour at sea, the behaviour of the *Resolution* in December 1893, performances under steam, manœuvring powers, relative size and cost of *Royal Sovereign* class, and the *Centurion* and *Barfleur* class. Unfavourable comments have been made on the *Royal Sovereign* class—the eight battle-ships of the Hamilton programme, of which the *Resolution* is one—because they have rolled heavily when small vessels have been comparatively steady. This, of course, is a circumstance for which the laws of nature are responsible rather than the designers of the ship; for however talented a naval architect may be, he cannot destroy natural laws, but can only seek to work so that they may be on his side, rather than fly in their face. To this end the constructor attempts to dispose dimensions and weights so that the natural period of oscillation of the ship may not synchronise with the period of waves more commonly encountered. A fair metacentric height is, of course, necessary in order that the ship may have stability, but an unduly large metacentric height tends to lessen the period of oscillation, and thus brings the period of the ship more nearly into harmony with that of waves ordinarily occurring. In fact, excessive stiffness produces undue motion amongst waves, whilst a very steady comfortable vessel might be one in danger of turning over under very small impulses. These facts are well known, of course, to those accustomed to the design of vessels, but they apparently are not fully grasped by many of those who go to sea in ships, to judge by the correspondence called forth by the *Resolution* incident. After the discussion that has been called forth by that incident, and the instruction given in connection with it, a hope may be expressed that "stability" and "steadiness" will not always be taken to accompany each other. The metacentric height of the *Royal Sovereign* class of the barbette type is 3½ feet, and past experience has shown that an excellent combination of stiffness and steadiness has been obtained with metacentric heights varying from 2¾ to 3½ feet. It may be taken for granted that it is desirable to give vessels a long period in order to gain steadiness, and with these big vessels the metacentre could be higher than in smaller craft, and, under extreme conditions of lading, the *Royal Sovereign* class could have as great a height as 4 feet without unduly impairing their prospect of steadiness, whilst of course the stiffness would be great. It is worthy of note that the inclining experiments made with the *Royal Sovereign* showed the calculated centre of gravity to be but 1¾ inches above the actual position; a result which speaks well for the care with which designs are got out at Whitehall. The period of oscillation of the *Royal Sovereign* with normal weights and 3½ feet metacentric height, is about eight seconds. This accords with the period of battleships which have acquired good reputations for steadiness in times past. Most of the latter ships, Mr. White tells us, have smaller metacentric heights, but they are also inferior in weight and moment of inertia; the latter, it must be remembered, having an important influence on the period of oscillation. Mr. White did not think it necessary to explain to a professional audience the manner in which rolling depends on the agreement between the period of the ship and the period of the wave, a fact that must be apparent to anyone who considers how a child's swing may be caused to oscillate through a wide range by small impulses applied at the right moment. Apparently the *Resolution* fell in with a sea, on the memorable occasion in the Bay of Biscay, which tilted her from side to side just as she herself was inclined to roll, whilst the little torpedo gun-boat *Gleaner*, which accompanied her, and made so much better weather of it, was not "fitted" by the big sea. In more moderate and more ordinary weather the relative conditions might have been reversed. In any case, it is as well to repeat, the *Resolution* at her greatest angle of roll had an ample margin of stability, and there was no reason to fear for the ship, although it was doubtless remarkably uncomfortable on board, and the captain exercised a wise discretion in coming back, having, as he did, an entirely untrained crew under him.

The paper by M. Emile Bertin treats with the subject of rolling of ships from a mathematical stand-point, carrying on the investigation of the question from a point where it was left by the late Prof. Jenkins, in a paper wherein he investigated the maximum effect which takes place at the extreme angle of roll. The author extends the theory to the effect at any intermediate part of the oscillation, and to the case in which the angle of maximum-righting moment may be less than a right angle. The difficulty of exact measurement of rolling is shown by the paper; a fact also well illustrated by Mr. White in the previous contribution. The ordinary pendulum instrument has been known to give indications 50 per cent. from truth, and it is evident that all statements as to the rolling of ships at sea—other than those obtained by a trained staff of observers with approved appliances—must be taken with a very large grain of salt.

On the second day of the meeting, Thursday, March 15, the proceedings opened with Mr. Ellis's very interesting paper on armour. This was another long contribution, with an appendix which gave results of all firing experiments on nickel steel and Harveyised armour that have taken place, excepting two, and one of these is to be included later. The other was made with a Harveyised steel plate so manifestly inferior as not to be considered fairly within the category. There was not much discussion of results or expression of opinion in the paper, and it would be useless to attempt to abstract the details of the trials. The memoir will remain a standard record of what has been done in this field up to the present time, and as such we must be content to leave it. The discussion which followed was much of the same nature as the paper; but the gratifying fact seemed apparent that at present English makers of armour-plates are somewhat ahead of their foreign competitors. How long it will be before the see-saw of inventive progress will again put another country in the front, remains to be seen, and doubtless depends chiefly to what extent monopoly is allowed to rule.

The leaves from Prof. Lewes's laboratory note-book did not form quite so valuable a paper as we are accustomed to get from him. A good deal that was said about combustion was certainly not new, even to the common engineer who has not made a special study of chemistry, and the many practical points missed seriously detracted from the value of the matter set forth. Thursday evening's sitting was the big one of the meeting, indeed we have seldom seen the theatre so overcrowded as it was when Sir Nathaniel Barnaby took the chair at seven o'clock. The water-tube boiler is *the* great marine engineering question of the day, and there was a prospect of it being fully discussed after the reading of the three papers that were on the list. The boiler has never received the attention it deserves at the hands of engineers, the steam-engine apparently affording a much more interesting field of research. The neglect has carried with it its own punishment, for the boiler has always been the most fruitful source of trouble to the marine engineer. To such an extent has this been the case of late that engineers have perforce had to turn their attention to the less interesting branch of machinery design. The advent of the three-stage compound engine, and the consequent demand for higher pressures, has emphasised the need for a new departure, although the introduction of the corrugated flue and the application of steel to boiler construction has delayed the crisis somewhat. These advantages have, however, been fully worked up, yet still there is a demand for further advance, and a large number of prominent marine engineers appear to think that the water-tube boiler, or pipe boiler—in which the water is inside the tubes, and the fire outside—is the proper solution of the problem. Mr. Thornycroft — the well-known torpedo boat builder, who took the leading part in introducing the locomotive type of boiler afloat—was perhaps the earliest of the present-day advocates of the water-tube boiler in this country to experiment and invent. The result of his labours is that he has produced a water-tube boiler at once safe, quick steaming, light, economical, and durable. The chief point which has led to the attainment of these desirable qualities is that he has been able to combine automatic and sufficient water circulation with small water spaces. His boiler consists of three horizontal cylinders which are placed so that in cross section of the boiler they are at the three angles of an imaginary triangle. The top cylinder at the apex is connected to the two cylinders at the base by two series of curved pipes which form the heating surface of the boiler. The grate is under the base of the triangle, and the whole is enclosed in a smoke-jacket or casing, the chimney naturally being at the top. The products of combustion pass among the tubes, and thence up the chimney. Outside the casing the top cylinder is connected to the two bottom cylinders by a couple of large pipes. The top cylinder may be from a foot to three feet in diameter, according to the size of the boiler; the bottom cylinders are considerably smaller, and the pipes forming the heating surface will be about one inch in diameter. The circulation of water, the chief feature which has led to the success of this steam generator, is obtained in this way:—When the one-inch pipes become heated, the water in them is turned partly into steam, and thus the mass becomes of less specific gravity than the column of solid water in the down-comer pipes outside the casing which connect the extreme end of the top cylinder to the extreme ends of the bottom cylinders. An ascending current of steam and water is thus set up in the tubes, whilst there must necessarily be a descending current in the down-comer pipes to compensate. In this way the water is always travelling round in a continuous stream, up the hot steam generating pipes, and down the colder down-comer pipes outside. Mr. Thornycroft has made some very pretty experiments with one of his boilers, which we lately had an opportunity of seeing at his works at Chiswick. He fitted a glass end—made of a number of sheets of plate-glass stuck together by a transparent cement—to the top horizontal cylinder, so that the circulation could be seen and measured. For the latter purpose a notched weir was put in the end of the cylinder, and the flow over it gauged according to the usual formula. The ends of the steam generating tubes could be seen spurting out water intermittently, and the circulation of water is so thorough that it was found by the weir measurements that the circulation of water was 105 times as rapid as the evaporation; that is to say, for each pound of steam generated 105 lbs. of water passed round the system, or, in other words, an equivalent of every pound of water passed 105 times round the cycle before being evaporated. It will be evident that with a volume of water sweeping with a rapidity such as this through the generating tubes, the surface would not be likely to be overheated, whatever the rate of combustion might be, and however fierce the fire. The problem of "drowned tubes" *v.* "above-surface tubes," which appears to be likely to be the burning question of the hour in water-tube boiler circles, is one into which we cannot enter here. Mr. Thornycroft is the leader of the "above-surface" school, whilst his great rival of the lower reaches, Mr. Yarrow, heads the "drowned tube" believers. Undoubtedly the Thornycroftians have more rapid circulation on their side; the question arises whether the Yarrovians have circulation enough.

Mr. Milton's paper consisted of a description of various types of water-tube boiler at present before the engineering world. It contains a large number of illustrations, and forms a valuable addition to his paper on the same subject read at the last summer meeting of the Institution held in Cardiff. Of Mr. Howden's paper it is not necessary to speak.

Friday's proceedings opened with a most interesting paper by Mr. Otto Schlick, whose investigations into the question of vibration of steam vessels will become classic. This further contribution carries the problem a step further, or, perhaps it should be said, enables the engineer to draw his conclusions with greater clearness. By means of a model designed to represent the hull of a steam vessel, the author showed the effect of placing various engines in different parts of the vessel. There were engines of many types—single, double, triple, and quadruple cranks. Pistons were weighted to represent difference in sequence of cylinders, and cranks were arranged at various angles. The model engines were shifted from part to part of the plank which represented the hull of the vessel. This plank, suspended from a frame by helical springs, naturally had a period of vibration of its own, which period was of the first order, *i.e.* with two nodal points; and as the engines were placed upon the nodes or else in other positions, the vibration was intensified or not when the revolutions of the engines reached that critical number, when synchronism was obtained between revolutions and the period of vibration of the plank or hull, according to the now well-known rule. We cannot pretend to give all the varying changes that were rung by Herr Schlick upon his model. Sometimes the changing of the high pressure for the low-pressure piston would start most violent oscillations, or *vice versa*, whilst the shifting of the engines to an equivalent of a few feet in an actual ship would have a really wonderful effect. For the details of these experiments we must refer our readers to the original paper, wherein both naval architects, engineers, physicists, and mathematicians may find matter of much interest.

Messrs. Read and Stanbury's paper is one of that admirable series on the subject of stress and strain in vessels upon which the first-named author especially has devoted so much time and thought. The present is a paper of almost purely professional interest, and is one with which it would be impossible to deal in brief. Mr. Taylor's paper was not read, Mr. Froude, in the absence of the author, giving an abstract. The problem of calculating the pressure and velocity of water at every point of the immersed surface of a ship, upon the lines and speed being given, is one which will long remain to be solved; but every step towards that end must be of interest, and the best way to proceed is naturally to divest the subject of those elements which tend to obscure its solution, and thus grapple with difficulties in detail. This the author proceeds to do by imagining a set of conditions which by no means exist. Thus, he supposes the surface of the water covered by rigid smooth ice, and the vessel to be flat-bottomed with vertical sides. In this way similar water lines are obtained, and the flow of water will be in plane stream lines only. This simplifies the work, since the methods and formulæ dealing with stream lines in two dimensions are much simpler than those for stream lines in three dimensions. The author proceeds to work out his problem on these lines at some length, and it will be evident from what has been said that it would be impossible to deal adequately with the question in a report such as this; in fact, the paper requires more study than we have been able to give to it up to the present. A short discussion followed the reading.

Mr. Stromeyer's paper discussed steam pressure losses in steam-engines due to various causes, such as friction of steam in pipes and passages; the spring of eccentric straps, rods, and links; inaccuracies in slide valve motion; piston leakage; throttling of steam, &c. Mr. Croll's paper dealt with a subject that has occupied the attention of marine engineers for some time past—the best method of working engines at lower powers; and Mr. Joy described his arrangement for reversing engines by means of an hydraulic cylinder placed inside the eccentric, so that an effect, in some respects, similar to that obtained by means of the loose eccentric is reached without the uncertainty of the latter device, and also with the further benefit of being able to "link up" or to stop the engines by making the eccentric disc coaxial with the shaft. The arrangement is certainly a very taking one, and appears to promise well, though of course such a tried device as link motion will not be ousted until any new arrangement has thoroughly proved its superiority.

The meeting terminated with the usual votes of thanks. The summer meeting will be held at Southampton, in July.

CHOLERA.[1]

If anyone had undertaken, thirty years ago, to classify the communicable diseases according to whether they are easy or difficult of prevention, he would have doubtless placed cholera, the disease I have chosen for the subject of this lecture, in the front rank amongst the non-preventible, or, at any rate, amongst those diseases that are preventible with very great difficulty; while, if anyone were at the present time to revise this classification, he would find himself in the fortunate position of placing cholera in the front rank amongst those diseases that are easily prevented; in fact, he would be able to tell you that the prevention of the spread of cholera is beset with less difficulty than that of some of the communicable diseases which in towns we have almost constantly among us, as, for instance, pneumonia, diphtheria, measles, and scarlet fever. Nothing could more forcibly illustrate the great advance in practical sanitation than the comparative immunity from cholera in an epidemic form, which this country has enjoyed for the last twenty-five years. By saying "comparative immunity," I am not forgetting that we have had cases of Asiatic cholera in this country during the last autumn, and it is precisely the remarkably limited character of this last outbreak which furnishes the best proof of our advance in sanitation, and gives satisfactory evidence of the correctness of the views on which the measures adopted for the prevention of the spread of cholera are based, and of the justification of placing cholera amongst the easily preventible diseases. To give you an idea of what sanitation has been able to do, and the complete success which attended the practice of good sanitation in preventing the spread of cholera, I will quote in illustration the following remarkable instance:[2]—A well-known fact which has received, unfortunately, a great many illustrations, is this: that pilgrims in India carry the contagium of cholera from the fairs or festivals, to which the disease is brought from the endemic area, to localities which were previously free from cholera. One such fair is particularly notorious, and it has in the past always been a source of the utmost anxiety to the Government of India; this is the great religious festival or Kumbh fair of Hardwâr, a town on the Ganges, but situated outside the endemic area of cholera. This great Kumbh occurs once in twelve years, and it is attended by large numbers of pilgrims, a proportion of these coming from districts in which cholera is always endemic. It has thus frequently happened that this great concourse of pilgrims has been followed by a wide diffusion of the disease. The great Kumbh is principally a religious festival, and is looked upon by Hindus as one of peculiar sanctity, and the very aim and object of their pilgrimage is to bathe in the sacred Ganges, and drink of its holy waters. In 1891, when the last Kumbh fair was held, 800,000 to 1,000,000 pilgrims assembled in Hardwâr; and to get an approximate estimation of the enormous pollution to which the sacred Ganges at Hardwâr is on this occasion subjected, and the great risk from cholera to which those who drink of its waters are exposed, I will mention what Dr. Simpson, the able health officer of Calcutta, states. In describing the scene at the "sacred pool" at Hardwâr—somewhat retired from the rest of the river—to bathe in which and to drink whose waters the pilgrims gather together in such multitudes, Dr. Simpson states that as the bathing of the pilgrims went on the clear stream became a muddy one; that from April 8 to 12 there was always passing through the sacred waters a "seething mass of humanity" in constant motion, passing through the pool at the rate of 400 to 500 per minute. You can easily picture to yourself that a few cases of cholera introduced into such a multitude, living under such conditions, would easily cause not only an outbreak of cholera there and then, but would by the returning pilgrims be carried far and wide. Thus a sanitary commissioner says of the Kumbh, previous to 1867: "Very little remains on record, but that little is a record of disease and death." In 1867, and again in 1879, the festival was followed by an epidemic outbreak of cholera, which on the latter occasion rapidly extended to the western districts. Now, all through the winter of 1890-91 there was much cholera in the north-west provinces and along the pilgrim routes below the hills. So grave was the outlook, that the question of prohibiting the fair to be held in April, 1891, was seriously discussed, and the official opinion of a civil-surgeon, in conformity with that of many other officials of great experience, was to the effect that "the most complete sanitary arrangement will be powerless to prevent the spread of cholera should the contemplated fair at Hardwâr be permitted to take place." Now mark what Mr. Ernest Hart says:

"The fair took place in April, 1891. In December, 1890, proceedings began at and about Hardwâr by the construction of seven bridges, by means of which access to the sacred pool from various parts was much facilitated. The whole of the site was then cleared of undergrowth, all filth was scraped away and removed, and arrangements made for the trenching of night soil. A small army of 1342 sweepers was engaged, and means were taken to prevent their desertion, an event which previous experience had shown to be not unlikely. The whole site was divided into sanitary sections, each with its temporary hospital and its sanitary patrol, every constable of which had his own fixed beat, within which he was instructed to (1) prevent overcrowding, (2) see to surface cleanliness, (3) give notice and remove nuisances, (4) report offenders, (5) remove those sick of infectious diseases, (6) see to the proper location of animals. The sanitary, police, and medical sections were made to correspond, each section being equipped with a special hospital, a number of constables, sanitary inspectors, an ambulance, and a large staff of conservancy men. Each section was thus complete and self-contained, and was directly responsible to the sanitary and deputy sanitary commissioners for the conditions of its own area. The members of the sanitary patrol had each their given beats, over which they exercised a constant supervision, acting also as detectives for sickness.

"The key to the sanitary management of the fair lay in the searching out and rapid removal of all cases of suspicious disease, in the maintenance of perfect cleanliness in the camp, and in the measures taken to prevent all possibility of contamination. Various improvements, however, were made in the conduct of the bathing festival, which were no doubt of great importance.

"The pilgrims coming from cholera-infected districts brought the infection with them, and two people died of undoubted cholera at Hardwâr during the most crowded period, but they were promptly isolated, and the infection did not spread. No

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[1] A Lecture delivered at the London Institution on February 15, 1894, by Dr. E. Klein, F.R.S.

[2] This account is taken from Mr. Ernest Hart's description in the *Daily Graphic*, September, 1893.